EVALUATION OF VARIOUS METHODS OF SOAKING SOIL-BITUMEN SPECIMENS

By

PHILLIP GORDON MANKE

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Oklahoma Agricultural

and

Mechanical College

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Thesis Approved:

Moreland Herrin
Thesis Adviser

Roger L. Handlin

Robert Woodside
Dean of the Graduate School

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION AND REVIEW OF THE LITERATURE

At the present time there is no one universal standard of bituminous stabilized soil design. There are many methods which have proven satisfactory, but the widely different procedures and apparatus lead to confusion and leave a standardized method highly desirable. Most of these methods of design have developed in various parts of the United States using different bituminous mixtures, construction procedures, types of soil, and subjected to different conditions of climate and use.

All of these methods of design use laboratory procedures in which some type of stability or strength value is determined for compacted soil-bitumen specimens. It has been found that satisfactory results are obtained when the design is selected from strength tests made on specimens which have been subjected to conditions as bad or worse than those expected in the field. Since a high moisture content causes a reduction in the strength of soil-bitumen mixtures, various methods of soaking these specimens have been devised in order to represent these detrimental conditions of the field in the laboratory.

In his work on the evaluation of soil strength

Terzaghi (13)[1] made the assumption that the soil subjected to stress was an isotropic, homogeneous, semi-infinite mass. Fundamentally, the theory dealing with stresses in any material is based on this assumption and, consequently, these same theoretical properties should exist in all materials being tested for strength. Therefore, when working with soil-bitumen mixtures, it is desirable to have specimens with the same moisture content throughout, since a variation from one portion of the specimen to another may result in an erroneous or misleading evaluation of its strength properties.

In reveiwing the literature it was found that there were many different methods of soaking soil-bitumen specimens. However, of the many methods proposed there appears to be three basic ones which have been used more prevalently. These are; the total immersion method, the one-half immersion method, and a method in which the specimens are subjected to a vacuum saturation process.

Both Rhodes (9) and Anderton (2) proposed the total immersion method of soaking in their work with tar-soil mixtures and this method is also used by the Oklahoma State Highway Department in soil-asphalt design. In this method the specimens are completely immersed in water at room temperature to a depth of one inch above the top of the specimen

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[1] The number in parentheses indicates the reference in the Bibliography.

and soaked for various periods of time. Rhodes used an 18 hour soaking time while Anderton let his specimens soak for 14 days. The Oklahoma State Highway Department recommends a 7 day soaking period.

The one-half immersion method was used by Roediger and Klinger (10) and later by Benson and Becker (3) in their research on soil stabilization. In this method the specimens are immersed in water to one-half their height and allowed to soak for various periods of time. Roediger and Klinger soaked their specimens for 7 days and Benson and Becker used a 5 day soaking period.

The vacuum saturation method, as it shall be referred to in this paper, was used by Holmes and Klinger (6) in their "Suggested Methods of Field Procedure for the Design of Cut-Back Asphalt-Soil Mixtures", and also by Thurston (14) in his testing method for stability of soil and liquid asphalt mixtures. In this method the specimens are placed in a water absorption box connected to a water reservoir. A vacuum is applied to the box and the system brought to 10 to 15 mm. absolute pressure which is maintained for 10 minutes. Water is then allowed to enter the box without increasing the pressure beyond that due to the vapor tension of the water. After 1500 ml. of water, enough to cover the specimens, has entered the box the system is closed and the reduced pressure maintained for an additional 10 minutes. Following this, the system is at once brought to

atmospheric pressure, the specimens removed, and immediately totally immersed for a period of 24 hours.

Other methods used less extensively include the "capillary absorption test" used by McKesson (8), Hovis (7), and Anderton (2), and a variation of the one-half immersion method used by Heriot (4) in which the specimens were immersed to a depth of one-fourth their height. However, for the purposes of this paper it was deemed advisable to investigate only the three aforementioned methods since they have been used more commonly and appear to be only variations of the one-half immersion method.

This paper is an attempt to evaluate some of the more common soaking tests and their results. The investigations have been made with a desire to find a method which is less time consuming and which will, as nearly as possible, result in a homogeneous moisture content throughout the soil-bitumen specimens.

CHAPTER II

MATERIALS AND LABORATORY PROCEDURE

Materials

The material used in this investigation is referred to as a "soil-asphalt" mixture. This term is applied to a product resulting when an asphaltic admixture is incorporated in a soil. Except for water then, there are two basic materials used in this study: soil and asphalt.

Soil

A A.A.S.H.O. Classification (1) A-4 type soil was used in the series of tests conducted. This soil was obtained from a roadside bank nine miles south and one mile east of Stillwater, Oklahoma. The soil is a combination of two soil horizons. It was mixed on a one to three ratio. Twenty-five percent of the "A" horizon (topsoil) to seventy-five percent of the "B" horizon (sandy red clay) were combined on a dry weight basis. The resulting mixture was considered typical of the soils stabilized with asphalt in the state of Oklahoma and meets Oklahoma State Highway Specifications, Section 313 (12) for Soil-Asphalt Base.

Table I shows the results of the wet sieve analysis

for this soil mixture and Table II lists the related soil properties.

TABLE I

SIEVE ANALYSIS OF SOIL MIXTURE

(25% "A" Horizon -- 75% "B" Horizon)

Sieve Size	#10	#40	#80	#200	Pan
% Passing	100	96.7	64.1	37.3	0

TABLE II

PROPERTIES OF SOIL MIXTURE

(25% "A" Horizon -- 75% "B" Horizon)

Atterberg Limits:	Liquid Limit ---	21%
	Plastic Limit --	16%
Fluff Point Range:	Upper ---------	5.5%
	Lower ---------	13.0%
Max. Density (Standard Proctor) ---		125.5 lb. per cu. ft.
Optimum Moisture Content ----------		11.0%

Asphalt

The asphalt used in this series of tests was a medium curing liquid asphalt meeting A.S.T.M. Specifications Designation MC-3. This asphalt was obtained from the Allied Materials Corporation in Stroud, Oklahoma and contained 14.5% hydrocarbon volatiles by weight. To obtain the soil-asphalt mixture used in the tests 5½% (dry weight basis) of this MC-3 asphalt cutback was added to the soil.

Preparation of Specimens

Specimens 4 in. in diameter and 2 in. high were used for all the tests. It was previously determined that approximately 2800 grams of soil were needed to mold three of these specimens.

The moisture contents of the two types of soil were determined. The soils were then combined on a dry weight basis in the one to three ratio. Following this, enough water was added to the soil in order to have 8% moisture on a dry weight basis in the combined mixture. After the addition of the water the soil mixture was put through a No. 10 sieve in order to break up the larger particles.

The mixture was then sealed in air tight containers for 24 hours. This allowed for a thorough dispersion of the water thoughout the mixture. Although some moisture was lost to the atmosphere during the sieving process, it was considered to have little effect on the test results, since the amount lost would be fairly constant for each batch of soil mixed.

After the 24 hour dispersion period the soil was removed from the containers and 5½% (dry weight basis) of the asphalt cutback was added. The soil and asphalt cutback were then mixed for a period of two minutes in a Hobart Model C-100 mixer. The mixture of soil and asphalt was then passed through a No. 4 sieve to break up any large sized particles and placed in an electric oven at

110°F. for various drying periods. The mixture was stirred frequently during these periods.

At the end of the drying period the mixture was removed from the oven and approximately 900 grams was used for each specimen molded. Since all specimens were molded in accordance with the Hveem-Gyratory Method (5) the amount of mixture needed for specimens 2 in. high varied with the length of the drying period. More of the mixtures dried for the shorter periods was required since they compacted more readily than those dried for the longer periods. After molding, each specimen was numbered and its weight and average height recorded. They were then immediately soaked in the respective manners.

Soaking Methods

In this work three methods of soaking were evaluated. These were; total immersion--in which the specimens were completely immersed in water, one-half immersion--in which specimens were immersed one-half their height in water and, vacuum saturation--in which specimens were first subjected to a vacuum and then allowed to soak completely immersed in water.

Total Immersion Method

For the total immersion and one-half immersion methods a special aluminum tray was constructed. This tray consisted of a thin sheet aluminum bottom with closely

spaced perforations mounted on four screw-legs so that the tray could be levelled. Using this tray the specimens were held above the bottom of the pan and the water was allowed better access to the bottoms of the specimens.

The tray was set in a shallow pan and levelled, then six specimens were placed on the tray and covered with water. The water level was adjusted and maintained at a level of one inch above the top of the specimens. Two of these specimens were allowed to soak at room temperature for two days, two for four days, and two for seven days. At the end of each soaking period two specimens were removed from the pan and the free moisture removed from the surfaces by blotting with paper towels. The specimens were then weighed and the average height of each determined.

Following this, a 2 in. diameter core was removed from the center of each specimen. This core was cut by means of a 2 in. inside diameter cylinder with a sharpened edge which was pressed through the center of the specimen. The core thus removed measured 2 in. in diameter and approximately 2 in. in height. After removal, the cores were laid on their sides and cut into thirds with a knife. The inner thirds of the two cores and the two outer two thirds were then crumbled up and combined. One hundred gram samples were then taken for moisture determinations.

Since the specimens were covered by approximately

one inch of water, the hydrostatic pressure on the bottom portions was only slightly higher than on the upper portions. The top and bottom portions of the specimens should have received about the same amount of soaking. The moisture content was, therefore, determined only for the inner and outer portions of the core. A description of the moisture determination procedure is found in the Appendix A.

One-half Immersion Method

The one-half immersion method of soaking was carried on in a moist room where the specimens were placed on the aluminum tray and the height of water in the pan adjusted and maintained at a height of 1 in. above the bottom of the specimens. As in the total immersion method two specimens were allowed to soak for two days, two for four days, and two for seven days. At the end of each soaking period two specimens were removed, the surface moisture removed by blotting, and the heights and weights recorded.

A 2 in. diameter core was then removed from the center of each specimen. Each core was then cut into thirds. Unlike the total immersion method moisture determinations were made on samples from the top, middle, and bottom thirds of the cores. This was done in order to determine the variations in moisture content throughout the specimens.

Vacuum Saturation Method

The vacuum saturation method of soaking is similar

to the method proposed by Holmes and Klinger (6). However, preliminary investigations indicate that for the soil-asphalt mixture being used, their method was too harsh, since specimens soaked in such manner were so soggy that they crumbled upon being removed from the water. Consequently, an adaptation of this method was worked out in order to obtain less critical conditions. The preliminary work also showed that the additional time of application of vacuum after the specimens were covered with water[2] had no influence on the amount of moisture absorbed and it was not used in the adopted method.[3]

After molding, the specimens were placed in a desiccator jar used as a water absorption box. Figure 1 shows a sketch of the apparatus used. A vacuum of 102 mm. absolute pressure was then applied to the jar, using a water aspirator, for a period of ten minutes. Deaired water was then allowed to fill the jar and cover the specimens.

The same vacuum pressure was maintained until the specimens were completely covered and then the jar was immediately brought to atmospheric pressure. A stop watch was started immediately and the specimens allowed to remain in the water for varying lengths of time. The specimens were then removed from the water and the height

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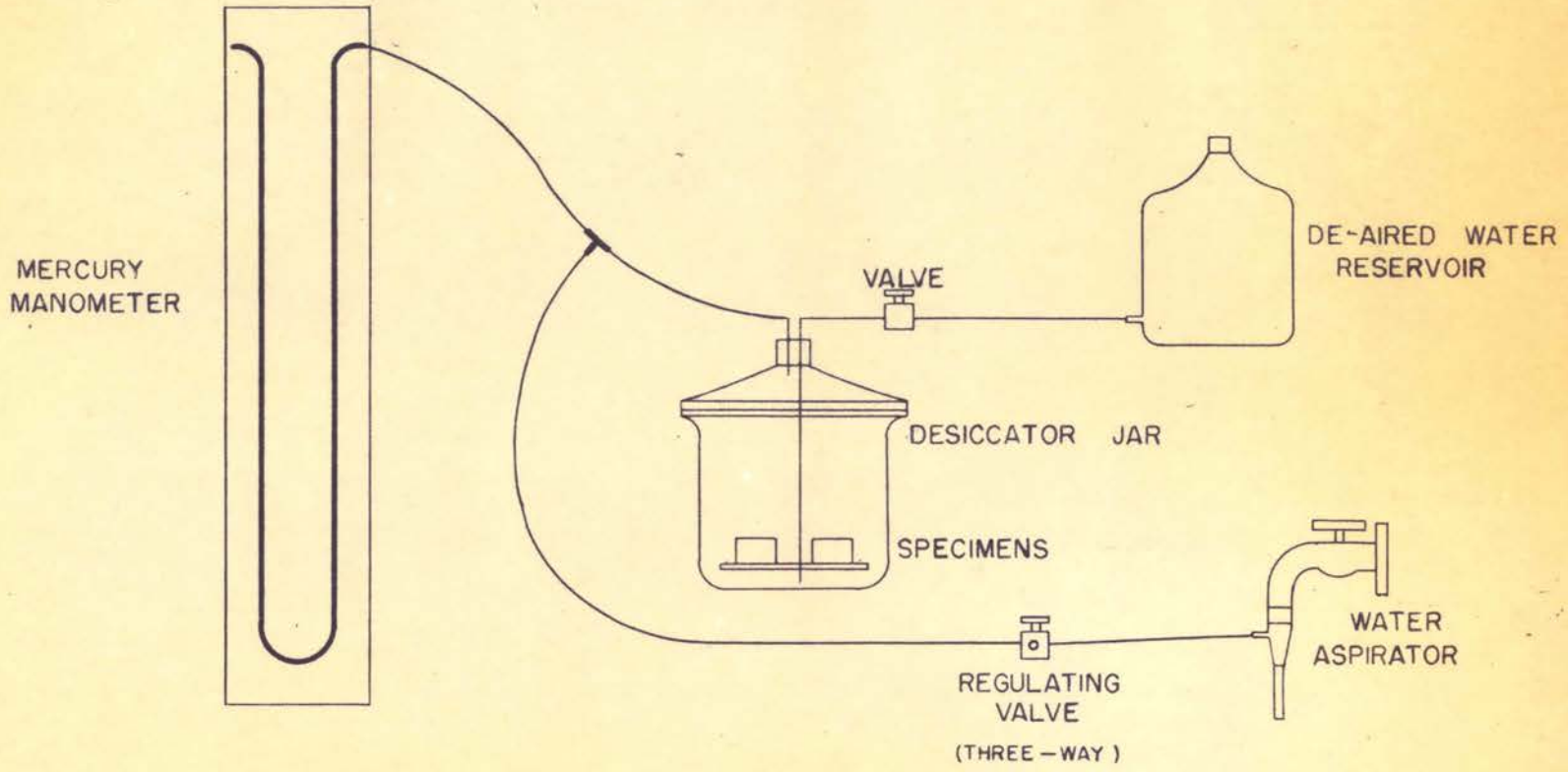
[2] See Holmes and Klinger method in Introduction.
[3] Refer to first data sheet in Appendix C.



SCHEMATIC DIAGRAM OF

APPARATUS FOR VACUUM SATURATION METHOD

Figure 1

and weight of the specimens determined. Cores were then taken from the center of each specimen and the moisture contents of the inner third and outer two thirds of the cores were determined by the standard laboratory tests.

CHAPTER III

RESULTS

The moisture determination tests were made on 100 gram representative samples taken from the cores removed from the soaked specimens. The tests determined the grams of water present in the 100 gram samples. These values were then converted to percent water content on a dry weight basis according to the sample calculations found in Appendix B.

The results of these tests have been tabulated below for each of the methods of soaking.

Total Immersion Method

% Water Content (D.W.B.) -- Inner 1/3 of Core

Curing Time (Hours)	Soaking Time (Days)			
	0	2	4	7
0	7.08	7.08	7.08	7.20
2½	5.32	5.31	5.31	5.44
5	3.42	3.48	3.82	4.63
10	1.92	2.25	2.91	4.26

% Water Content (D.W.B.) -- Outer 2/3 of Core

Curing Time (Hours)	Soaking Time (Days)			
	0	2	4	7
0	7.08	7.65	7.82	8.25
2½	5.32	6.90	7.67	8.55
5	3.42	7.32	8.40	9.25
10	1.92	8.15	9.63	11.70

One-Half Immersion Method

% Water Content (D.W.B.) -- Top 1/3 of Core

Curing Time (Hours)	Soaking Time (Days)			
	0	2	4	7
0	7.08	7.08	7.08	7.08
2½	5.32	5.32	5.32	5.32
5	3.48	3.48	3.48	3.92
10	1.92	2.14	2.47	3.24

% Water Content (D.W.B.) -- Middle 1/3 of Core

Curing Time (Hours)	Soaking Time (Days)			
	0	2	4	7
0	7.08	7.08	7.35	7.35
2½	5.32	5.55	5.62	5.67
5	3.48	3.48	3.48	4.05
10	1.92	1.97	2.47	4.60

% Water Content (D.W.B.) -- Bottom 1/3 of Core

Curing Time (Hours)	Soaking Time (Days)			
	0	2	4	7
0	7.08	7.82	8.20	8.68
2½	5.32	6.97	7.70	8.93
5	3.48	6.26	8.90	13.30
10	1.92	8.25	12.80	16.10

Vacuum Saturation Method

Soaking Time (Min.)	% Water Content (Dry Wt. Basis)	
	Inner 1/3 of Core	Outer 2/3 of Core
0	4.62	4.62
½	8.42	9.80
1	9.17	11.45
2½	10.30	13.00
5	11.45	13.05
10	11.95	13.55
15	12.10	13.70

CHAPTER IV

DISCUSSION OF RESULTS

The results of the moisture determination tests run on the cores taken from specimens soaked by the various methods have been plotted on curves. These curves show for the different portions of the cores the percent water content on a dry weight basis plotted against the time of soaking. The individual curves represent specimens which were molded from mixtures dried in the oven for a specific period of time.

Total Immersion Method

The curves for the outer portions of the cores in Figure 2 show definitely that there is an increase in the amount of water absorbed with an increase in drying time of the mixture. There is also a tendency for the curves to level off as the time of soaking increases. This is an indication that there is a point of saturation at which there will be no further increase in the amount of moisture absorbed. However, this was not definitely established in this study.

The increase in water absorption with an increase in drying time is not as evident in the inner portions of the specimens. In fact, it appears from Figure 3 that specimens

RELATION OF % WATER CONTENT TO SOAKING TIME

FOR OUTER $\frac{2}{3}$ OF CORE

SPECIMENS TOTALLY IMMERSED

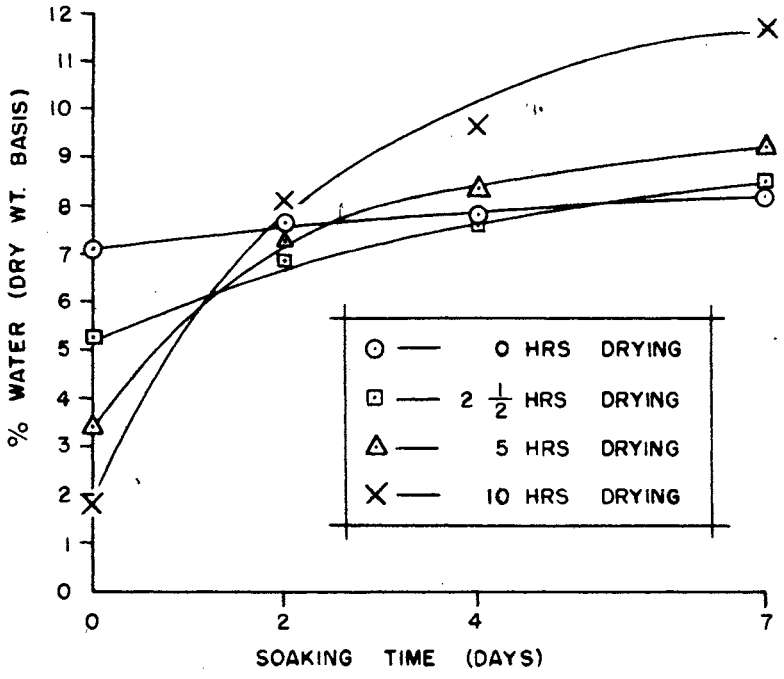


Figure 2

RELATION OF % WATER CONTENT TO SOAKING TIME

FOR INNER $\frac{1}{3}$ OF CORE

SPECIMENS TOTALLY IMMERSED

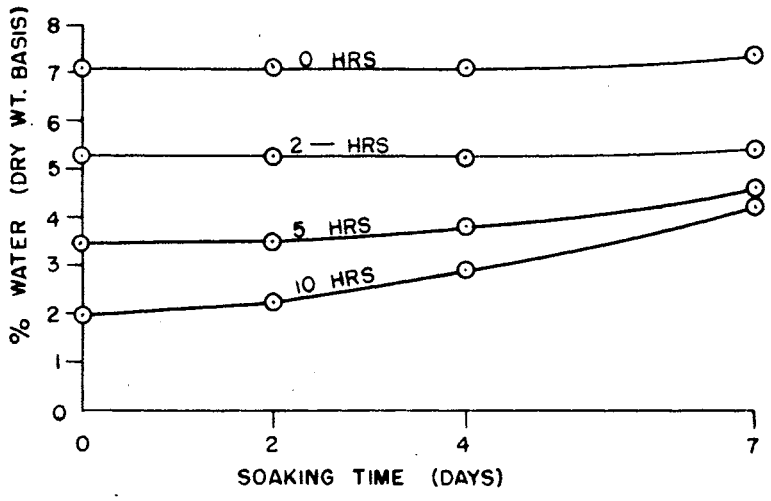


Figure 3

molded from mixtures dried for 0 and 2½ hours contained greater percentages of water at 7 days than those made from mixtures dried for the 5 and 10 hour periods. However, it must be remembered that this water was present in the soil-asphalt mixture when molded and was not derived by absorption.

The moisture content increase of the different portions of the cores over a 7 day soaking period is shown in Table III. A comparison of the values shows the percent increase is much less for the middle third of the cores than for the outer two-thirds. It appears that little or no moisture reaches the inner portion of the specimens during the first few days of soaking, and that for increases in moisture content comparable to those of the outer portions a protracted time of soaking would be necessary.

TABLE III

MOISTURE CONTENT INCREASE FOR 7 DAY SOAKING PERIOD

(Total Immersion Method)

Curing Time (Hours)	Percent Increases	
	Inner 1/3	Outer 2/3
0	0.12	1.17
2½	0.14	3.25
5	1.21	5.83
10	2.34	9.78

In the early stages of their work Roediger and Klinger (11) obtained results which indicated that "air-blocking"

frequently occurred in samples soaked totally immersed. This "air-blocking" occurs when the air is trapped and held in the voids of the specimen by water pressure. Since the air cannot escape the water cannot displace it and the soaking is retarded. This conception is borne out by these results which show the lack of soaking in the inner portions.

The calculated densities and percent air voids of specimens molded from mixtures dried for the various lengths of time are shown in Table IV. The densities of the specimens decrease with increased drying time and, therefore, the percent air voids is increased. This provides easier access and more space for the water that is absorbed. From this it is evident that the water absorbing properties of the soil-asphalt mixture increase with an increase in the drying period before compaction.

TABLE IV

DENSITY AND PERCENT AIR VOIDS
OF MOLDED SPECIMENS

Drying Time (Hrs.)	Density lb./cu. ft.	% Air Voids
0	137.2	0.80
$2\frac{1}{2}$	135.0	4.60
5	128.2	11.60
10	123.5	11.80

One-Half Immersion Method

In considering this method of soaking it was believed that the moisture content would vary considerably from the bottom to the top of the specimens. Therefore, moisture determinations were made on the top, middle, and bottom thirds of the cores cut from the soaked specimens. Figures 4, 5, and 6 show the results obtained from these determinations.

Figure 4 shows that for the shorter drying periods (0 and 2½ hours) there is no increase in moisture content over a 7 day soaking period in the upper protions of the specimens. Only slight increases, 0.44% and 1.34%, are noted for the 5 and 10 hour drying periods.

The middle portion of all the specimens shows increases in moisture content for the 7 day soaking period. The increase is very slight for those made from mixtures dried for 0 and 2½ hours, with a 2.7% increase for those made from mixtures dried for 10 hours. The specimens made from mixtures dried for 5 hours show an increase of 0.57% which is slightly higher than the 0.44% increase in the top portion.

The small difference between the increases in moisture content of the top and middle portions might lead to the conclusion that the amount of soaking for the 7 day period was practically the same in this case. However, observations made at the time the cores were removed tended

RELATION OF % WATER CONTENT TO SOAKING TIME

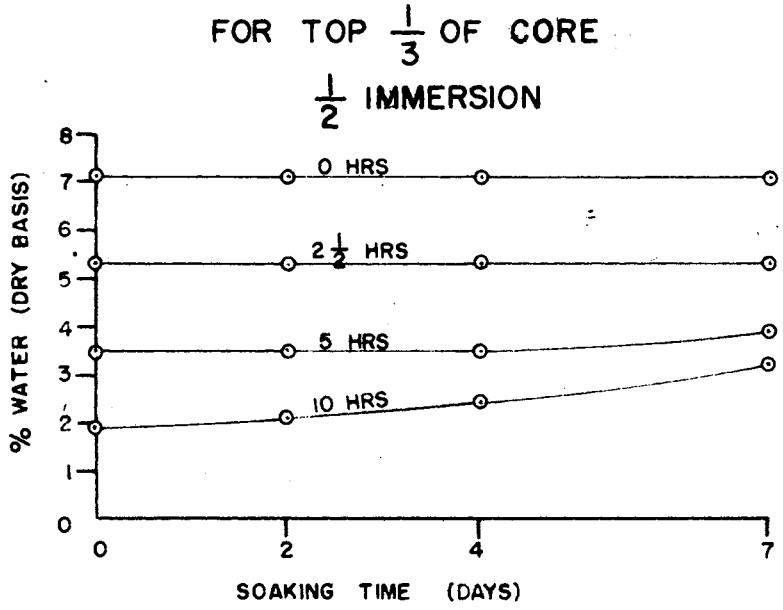
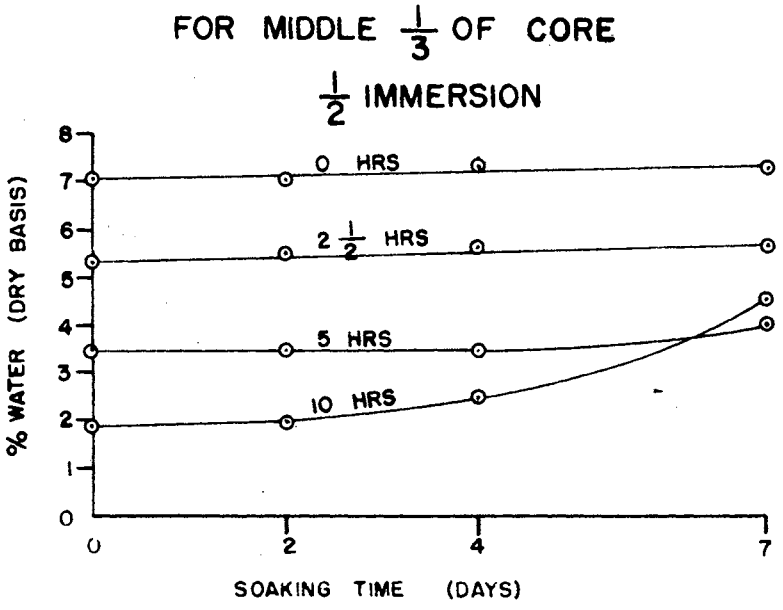


Figure 4



NUMBER OF HOURS — DRYING TIME

Figure 5

RELATION OF % WATER CONTENT TO SOAKING TIME

FOR BOTTOM $\frac{1}{3}$ OF CORE

$\frac{1}{2}$ IMMERSION

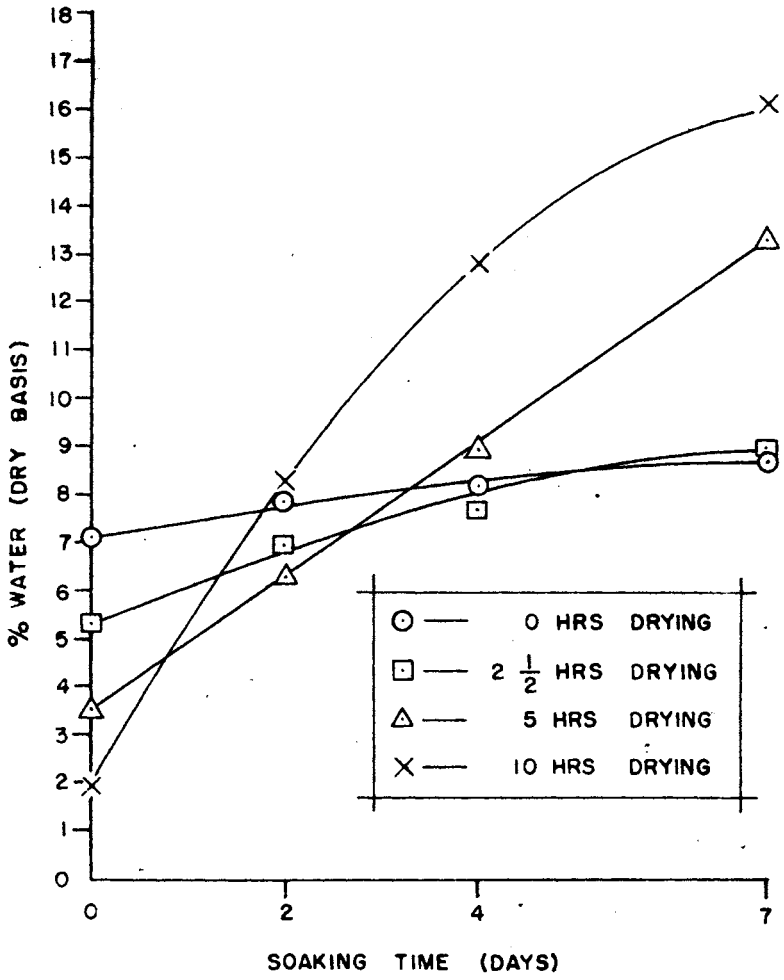


Figure 6

to disprove this. As the water was absorbed into the specimens it caused the soaked portions to turn a darker color than the unsoaked portions. From this color change in the core it was possible to estimate the height to which the absorbed water had progressed in the soaked specimens. From these observations it is believed that a major part of the increased moisture in the top portions of the specimens was derived from the moist atmosphere of the humid room and that little water soaked up from the bottom.

For this method of soaking the bottom portions of the specimens show the greatest increase in moisture content. Here again, as in the total immersion method, there is an increase in the amount of moisture absorbed with an increase in drying time. This increase for the various portions of the core is shown in Table V. The curves in Figure 6 also show this increase and indicate the levelling off tendency toward a point of saturation. This is not exhibited by the top and middle portions of the specimens. The increase in water content that does occur in these portions takes place very slowly in comparison with that of the bottom of the specimens.

In Table V the percent increase in moisture content has been tabulated for the various portions of the cores. These increases were obtained by subtracting the percent water content of the initial soil-asphalt mixtures from the percent water content of the top, middle, and bottom thirds of the cores at the end of the 7 day soaking period.

TABLE V

MOISTURE CONTENT INCREASE FOR 7 DAY SOAKING PERIOD

(One-Half Immersion Method)

Curing Time (Hours)	Percent Increases		
	Top 1/3	Middle 1/3	Bottom 1/3
0	0.00	0.27	1.60
2½	0.00	0.35	3.61
5	0.44	0.57	9.82
10	1.34	2.70	14.20

Vacuum Saturation Method

Due to a limited amount of time available for the evaluation of this method of soaking, and since the preliminary investigations indicated that this method was too harsh for specimens molded from very dry mixtures, all results were obtained using only specimens molded from soil-asphalt mixtures dried for 2½ hours before molding.

Again, as in the total immersion method, it was considered that the top and bottom portions of the specimens would receive about the same amount of soaking and that the only variation would occur in the inner portions. Consequently, moisture determinations were made only for the inner and outer sections of the cores removed from the soaked specimens. The results of these determinations are shown in Figures 7 and 8. In these graphs the percent water content (dry weight basis) of the inner and outer

RELATION OF % WATER CONTENT TO SOAKING TIME

FOR OUTER $\frac{2}{3}$ OF CORES FROM SPECIMENS SOAKED BY VACUUM METHOD AT 102 mm ABSOLUTE PRESSURE

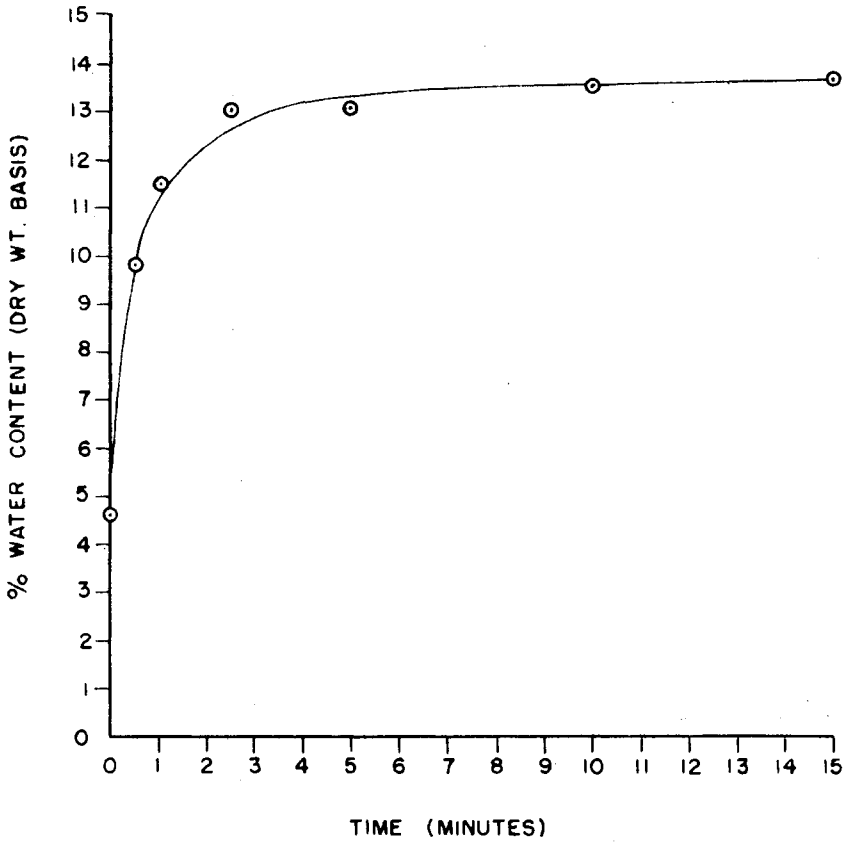


Figure 7

RELATION OF % WATER CONTENT TO SOAKING TIME

FOR INNER $\frac{1}{3}$ OF CORES FROM SPECIMENS SOAKED BY VACUUM METHOD AT 102 mm ABSOLUTE PRESSURE

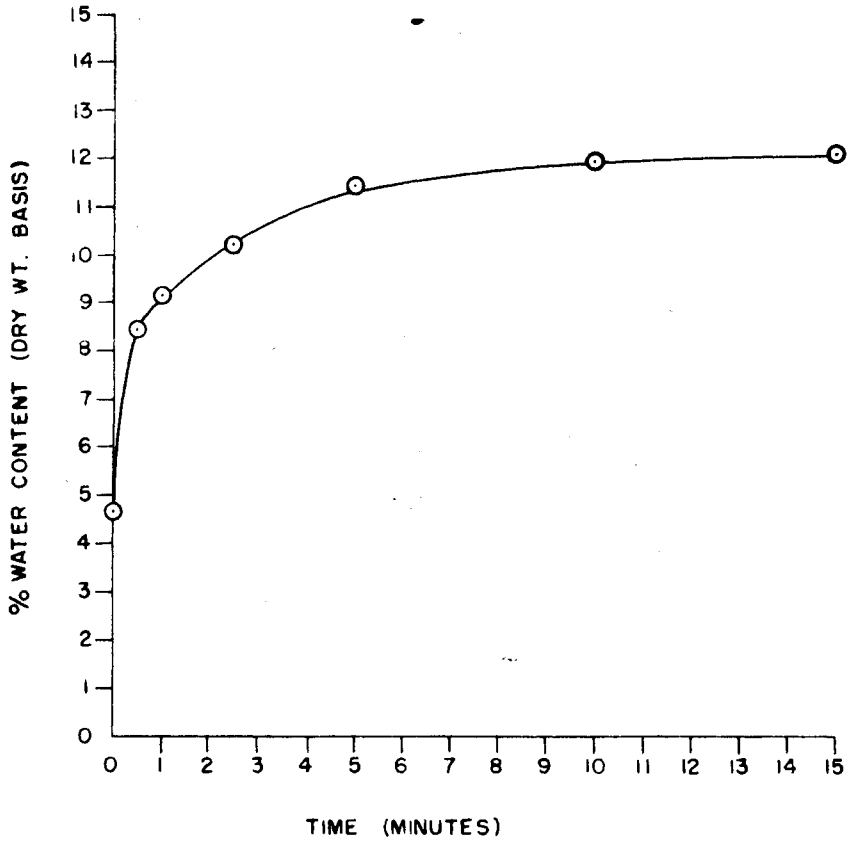


Figure 8

parts of the cores is plotted against the time of soaking in minutes after removal of the vacuum.

Figure 7 indicates that for the outer portions of the specimens, water is absorbed very rapidly after the vacuum pressure is released and that after about two minutes those portions, for all practical purposes, have reached their saturation points. Further evidence of this was obtained in observations made at the time the specimens were removed from the water. Those specimens removed after soaking from 0 to 2 min. exhibited qualities similar to those of a blotter, in that the water adhering to the surfaces when removed from the jar was immediately absorbed into the specimen. The specimens removed after soaking longer than 2 min. exhibited this tendency to a lesser degree and in many instances the water on the outer surfaces had to be removed by blotting with paper towels.

The inner third of the cores also show a high rate of absorption during the first few minutes after release of the vacuum. This is shown in Figure 8. However, the increase in moisture content is not as great nor as rapid as for the outer two-thirds. The reason for this is that in order to penetrate to the innermost portions of the specimen the water has to travel a greater distance and overcome larger resistances than it does in the outer portions.

Both of the curves in Figures 7 and 8 exhibit a levelling off as the time of soaking increases and, although the percent water content in the inner portions is at all

times less than that of the outer portions, the difference is very small. The difference in moisture content for the various times of soaking between the inner third and outer two-thirds of the cores is shown in Table VI.

TABLE VI

VARIATION IN PERCENT WATER CONTENT FOR INNER 1/3 AND OUTER 2/3 OF CORES

(Vacuum Saturation Method)

Soaking Time (Min.)	Percent Water Content (Dry Wt. Basis)		
	Outer 2/3	Inner 1/3	Difference
0	4.62	4.62	0
½	9.80	8.42	1.38
1	11.45	9.17	2.28
2½	13.00	10.30	2.70
5	13.05	11.45	1.60
10	13.55	11.95	1.60
15	13.70	12.10	1.60

The observations of the "blotter effect" exhibited by the specimens serve to illustrate the mechanics of this vacuum saturation method of soaking. When a vacuum is applied to the specimens a portion of the air occupying the void spaces is pulled out and tiny partial vacuums are created. If this vacuum pressure is maintained after the specimens are covered with water the force pulling the air out of the pores in the specimen hinders the flow of water

into the pores produced by capillary action and the small hydrostatic pressure. This retards the amount of soaking that takes place. However, when the specimens are brought back to atmospheric pressure the water is forced into the voids by the suction of these small vacuums and the pressure of the atmposhere and in a few minutes time the specimens are thoroughly saturated.

The amount of water absorbed by the specimens was found to depend upon the time of soaking after the vacuum was removed. It appears likely that the initial absolute pressure that is applied to the system and the drying time of the specimens (air voids) will also have an influence on the amount and rate of absorption.

The vacuum saturation method of soaking appears to be the best of the three methods that were investigated. It required much less time in the soaking process than the other methods and gave a more complete and uniform distribution of the absorbed water throughout the specimens.

Suggestions For Further Investigations

Further investigations of the vacuum saturation method should be made to determine the effect that variations in the initial absolute pressure will have on the amount of water absorbed by the soil-asphalt specimens. The effect of variations in the time of application of this vacuum pressure should also be determined.

Through the regulation of this vacuum pressure, its

time of application, and the time of soaking after its removal, it may be possible to accurately control the amount of moisture absorbed. If this control is possible, then additional work should be done toward the establishment of some criteria of soaking amounts needed for design under various climatic conditions. Since design procedures in areas with wet climates would require a greater degree of soaking for the specimens than would the same procedures in more arrid regions, these standards of soaking could lead to the adoption and standardization of this method of soaking for all conditions.

In connection with this, there is a need for additional research on the strength values of specimens soaked by the vacuum saturation method and comparisons made with those values obtained for specimens soaked by the other methods.

CHAPTER V

CONCLUSIONS

The evaluation of the three basic soaking methods has been made in order to obtain a comparison between the moisture absorbing characteristics of soil-asphalt specimens when soaked in the various manners. The results of these investigations show that the absorbent qualities of the specimens is increased as the percent of air voids in the specimens increases. The investigations have also shown that of the three methods the vacuum saturation method is the most desirable since it requires such a short time of soaking and results in a more thorough and equal distribution of the absorbed water.

Conclusions: Total Immersion Method of Soaking

1. In the outer portions of the specimens the amount of water absorbed increases with an increase in drying time of the original mixture. This increase is related to the percent of air voids in the specimens.

2. The increase in water content of the inner portions of the specimens is much less than in the outer portions.

3. This lack of soaking in the inner portions of

the specimens is an indication that "air-blocking" does occur in specimens soaked totally immersed.

Conclusions: One-Half Immersion Method of Soaking

1. There is a wide variation in the water content of the top, middle, and bottom sections of the specimens soaked by this method.

2. The bottom portions of the specimens receive the greatest amount of soaking and the amount of water absorbed increases with an increase in drying time of the soil-asphalt mixture.

Conclusions: Vacuum Saturation Method of Soaking

1. This method requires a very short period of soaking as the specimens almost reach their saturation points within a few minutes after the vacuum pressure is released.

2. There is only a slight variation in water content throughout the soaked specimens.

3. Maintenance of the vacuum pressure after the specimens are covered with water has little effect on the amount of water absorbed.

4. The amount of water absorbed depends on the time of soaking after removal of the vacuum.

5. Even at low absolute pressures (102 mm. of mercury) the specimens were so thoroughly saturated that this can be considered a very critical method of soaking.

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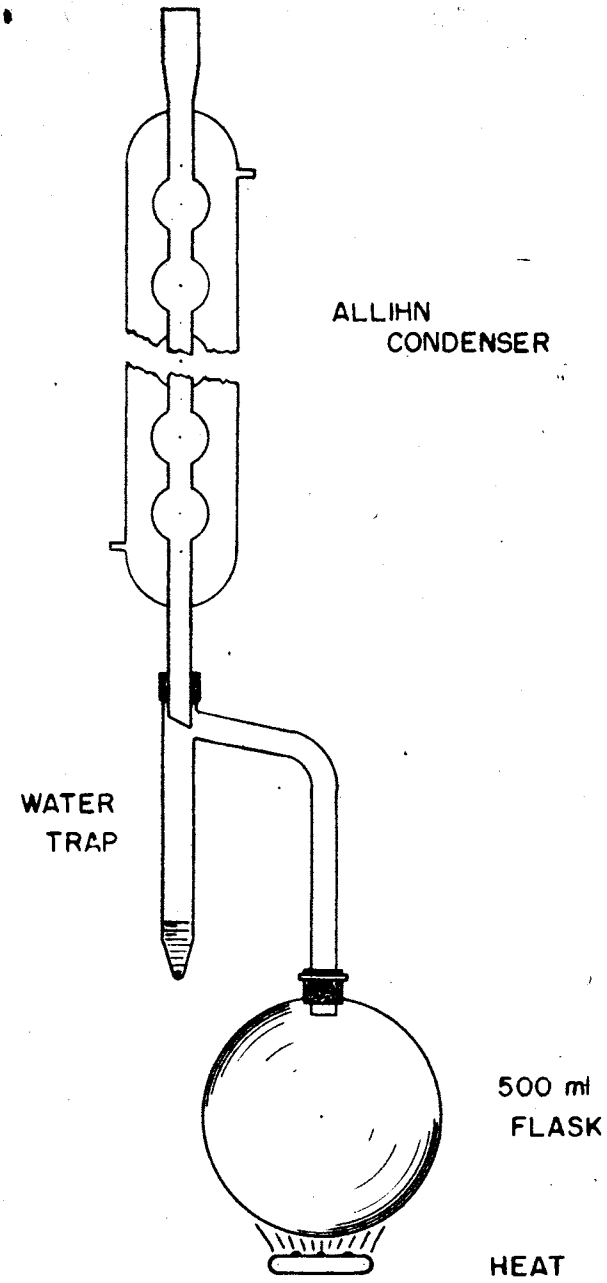
APPENDIX A

MOISTURE DETERMINATION TEST

1. A 100 gram representative sample of the soaked soil-asphalt specimen was placed in a 500 ml. round bottom flask.
2. Approximately 200 ml. of purified Xylene was added to this 100 gram sample and the mixture agitated.
3. The flask and its contents were then clamped to a ring stand with a water trap and an Allihn condenser arranged as shown in Figure 9. A source of water supply was connected to the condenser at the bottom and an over flow tube attached at the top.
4. A gas burner was placed beneath the flask and the contents allowed to boil at a moderate rate for a period of five hours. The condensed liquid collected in the water trap with the water at the bottom and the Xylene (specific gravity less than 1.0) on top.
5. The bottom portion of the water trap was graduated in milliliters and at the end of the boiling period the amount of water present in the original 100 gram sample was read directly from the trap.



APPARATUS FOR DETERMINING
PERCENT OF WATER

Figure. **9**

APPENDIX B

SAMPLE CALCULATIONS

The amount of water in grams per 100 grams of soil-asphalt sample was converted to percent water content on a dry weight basis by the following formula:

$$w = \frac{W_w \ (\ 100 \not - b \not - v \ )}{100 - W_w}$$

in which w = % water (dry soil wt. basis)

b = % asphalt bitumens (dry soil wt. basis)

v = % hydrocarbon volatiles (dry soil wt. basis)

W_w = % water (total wt. basis) = $\frac{\text{wt. of water} \times 100}{\text{total wt. of sample}}$

The percent of asphalt bitumens (b) present was determined from a distillation test of the MC-3 asphalt cut-back and amounted to 4.7% when using 5½% cut-back (dry wt. basis) in soil-asphalt mixture. The hydrocarbon volatiles (v) present in the soil-asphalt mixture after the various drying periods were 0.8% for 0 hours drying, 0.57% for 2½ hours, 0.41% for 5 hours, and 0.24% for 10 hours. These values were obtained from distillation tests performed by Dr. Moreland Herrin.

Example:

A 100 gram representative sample contains 4.6 grams of water. The specimen from which the core was removed was made from a soil-asphalt mixture dried for 5 hours.

$$W_w = \frac{4.6 \times 100}{100} = 4.6\%$$

$$b = 4.7\%$$

$$v = 0.41\%$$

$$w = \frac{4.6\ (100 \neq 4.7 \neq 0.41)}{100 - 4.6}$$

$$w = \frac{4.6\ (105.11)}{95.4}$$

$$w = 5.07\%$$

APPENDIX C

DATA SHEETS

Preliminary Investigations Of Vacuum Saturation Method:

The following test results were obtained using the vacuum saturation method. Specimens were subjected to 102 mm. absolute pressure for 10 minutes and water was then allowed to enter the box. After the specimens were covered with water the pressure was maintained for varying periods of time and then released. After the system was brought back to atmospheric pressure the specimens were immediately removed from the water and cores taken from the center of each specimen. Time in the following table represents the additional time of application of vacuum after the specimens were covered with water.

Water Content (Grams Per 100 Grams)

Time	Portion of Core		Difference
	Outer 2/3	Inner 1/3	
0	9.6	7.9	1.7
$2\frac{1}{2}$	10.4	8.6	1.8
5	10.0	8.2	1.8
10	10.1	8.3	1.8

Total Immersion Method of Soaking:

0 Hours Drying Time

Soaking Time	2 Days		4 Days		7 Days	
No. of Specimen	1	2	3	4	5	6
Ht. Before Soaking in.	1.97	2.00	2.00	2.00	2.00	2.00
Ht. After Soaking in.	1.985	2.015	2.017	2.023	2.030	2.035
Wt. Before Soaking gms.	892.5	907.5	910.0	908.0	908.5	908.5
Wt. After Soaking gms.	900.5	916.0	919.5	918.0	920.0	921.0

Moisture Determination Results

Water Content (Grams Per 100 Grams)

Soaking Time (Days)	Portion of Core	
	Inner 1/3	Outer 2/3
Unsoaked	6.30	
2	6.30	6.75
4	6.30	6.90
7	6.40	7.25

2½ Hours Drying Time

Soaking Time	2 Days		4 Days		7 Days	
No. of Specimen	1	2	3	4	5	6
Ht. Before Soaking in.	1.91	2.01	2.00	2.00	2.03	2.03
Ht. After Soaking in.	1.927	2.027	2.040	2.045	2.070	2.073
Wt. Before Soaking gms.	850.5	895.0	895.5	894.0	892.5	895.0
Wt. After Soaking gms.	869.5	916.0	922.5	921.5	933.0	932.0

Moisture Determination Results

Water Content (Grams Per 100 Grams)

Soaking Time (Days)	Portion of Core	
	Inner 1/3	Outer 2/3
Unsoaked	4.80	
2	4.80	6.15
4	4.80	6.80
7	4.90	7.50

5 Hours Drying Time

Soaking Time	2 Days		4 Days		7 Days	
No. of Specimen	1	2	3	4	5	6
Ht. Before Soaking in.	1.91	1.98	2.00	2.00	2.00	2.00
Ht. After Soaking in.	1.950	2.000	2.040	2.050	2.050	2.060
Wt. Before Soaking gms.	804.0	845.0	846.5	847.0	847.0	847.5
Wt. After Soaking gms.	836.0	878.0	887.5	889.0	895.0	898.0

Moisture Determination Results

Water Content (Grams Per 100 Grams)

Soaking Time (Days)	Portion of Core	
	Inner 1/3	Outer 2/3
Unsoaked	3.15	
2	3.20	6.50
4	3.50	7.40
7	4.22	8.10

10 Hours Drying Time

Soaking Time	2 Days		4 Days		7 Days	
No. of Specimen	1	2	3	4	5	6
Ht. Before Soaking in.	1.93	2.00	2.00	2.00	2.00	2.00
Ht. After Soaking in.	1.980	2.060	2.080	2.090	2.080	2.090
Wt. Before Soaking gms.	798.5	826.0	825.5	826.0	826.5	825.0
Wt. After Soaking gms.	844.5	874.5	886.0	886.0	893.5	896.0

Moisture Determination Results

Water Content (Grams Per 100 Grams)

Soaking Time (Days)	Portion of Core	
	Inner 1/3	Outer 2/3
Unsoaked	1.80	
2	2.10	7.21
4	2.60	8.40
7	3.90	10.02

One-Half Immersion Method of Soaking:

0 Hours Drying Time

Soaking Time	2 Days		4 Days		7 Days	
No. of Specimen	1	2	3	4	5	6
Ht. Before Soaking in.	2.00	2.00	2.00	2.00	2.00	2.00
Ht. After Soaking in.	2.00	2.00	2.00	2.00	2.00	2.005
Wt. Before Soaking gms.	906.5	906.5	903.0	906.5	906.5	907.0
Wt. After Soaking gms.	911.0	911.5	909.5	913.5	913.0	913.0

Moisture Determination Results

Water Content (Grams Per 100 Grams)

Soaking Time (Days)	Portion of Core		
	Top 1/3	Middle 1/3	Bottom 1/3
Unsoaked	6.30		
2	6.30	6.30	6.90
4	6.30	6.50	7.20
7	6.30	6.50	7.60

2½ Hours Drying Time

Soaking Time	2 Days		4 Days		7 Days	
No. of Specimen	1	2	3	4	5	6
Ht. Before Soaking in.	1.98	2.00	2.00	2.01	2.01	2.01
Ht. After Soaking in.	2.015	2.020	2.035	2.040	2.075	2.070
Wt. Before Soaking gms.	889.0	899.5	900.5	901.5	902.0	898.0
Wt. After Soaking gms.	898.0	909.0	913.0	914.5	920.5	916.0

Moisture Determination Results

Water Content (Grams Per 100 Grams)

Soaking Time (Days)	Portion of Core		
	Top 1/3	Middle 1/3	Bottom 1/3
Unsoaked	4.80		
2	4.80	5.00	6.20
4	4.80	5.05	6.80
7	4.80	5.10	7.80

5 Hours Drying Time

Soaking Time	2 Days		4 Days		7 Days	
No. of Specimen	1	2	3	4	5	6
Ht. Before Soaking in.	2.01	2.01	2.02	2.01	2.04	1.98
Ht. After Soaking in.	2.050	2.050	2.070	2.077	2.100	2.065
Wt. Before Soaking gms.	847.0	844.0	844.0	845.0	842.0	827.5
Wt. After Soaking gms.	860.5	858.5	865.5	869.5	882.0	870.0

Moisture Determination Results

Water Content (Grams Per 100 Grams)

Soaking Time (Days)	Portion of Core		
	Top 1/3	Middle 1/3	Bottom 1/3
Unsoaked	3.20		
2	3.20	3.20	5.60
4	3.20	3.20	7.80
7	3.60	3.70	11.20

10 Hours Drying Time

Soaking Time	2 Days		4 Days		7 Days	
No. of Specimen	1	2	3	4	5	6
Ht. Before Soaking in.	2.04	2.02	2.02	2.01	2.00	2.00
Ht. After Soaking in.	2.120	2.095	2.110	2.110	2.110	2.112
Wt. Before Soaking gms.	823.5	808.0	805.5	804.0	801.5	803.0
Wt. After Soaking gms.	849.0	833.5	846.0	848.5	851.5	856.0

Moisture Determination Results

Water Content (Grams Per 100 Grams)

Soaking Time (Days)	Portion of Core		
	Top 1/3	Middle 1/3	Bottom 1/3
Unsoaked	1.80		
2	2.00	1.85	7.30
4	2.30	2.30	10.90
7	3.00	4.20	13.30

Vacuum Saturation Method of Soaking:

Soaking Time min.	½		1		2½	
Specimen No.	1	2	1	2	1	2
Ht. Before Soaking in.	2.00	2.01	2.00	2.00	1.99	2.00
Ht. After Soaking in.	2.04	2.05	2.04	2.06	2.03	2.04
Wt. Before Soaking gms.	873.5	875.5	875.0	876.0	873.5	877.0
Wt. After Soaking gms.	923.0	928.0	935.5	937.5	933.0	937.5

(Continued)

Soaking Time min.	5		10		15	
Specimen No.	1	2	1	2	1	2
Ht. Before Soaking in.	1.99	2.00	1.99	2.00	2.01	2.01
Ht. After Soaking in.	2.04	2.05	2.05	2.08	2.09	2.10
Wt. Before Soaking gms.	874.5	877.0	875.0	878.0	874.0	873.5
Wt. After Soaking gms.	938.5	944.0	945.0	954.0	960.0	963.0

Moisture Determination Results

Water Content (Grams Per 100 Grams)

Soaking Time (Min.)	Portion of Core	
	Inner 1/3	Outer 2/3
Unsoaked	4.20	
½	7.40	8.50
1	8.00	9.80
2½	8.90	11.00
5	11.45	13.05
10	11.95	13.55
15	12.10	13.70

VITA

Phillip Gordon Manke

Candidate for the Degree of

Master of Science

Thesis: EVALUATION OF VARIOUS METHODS OF SOAKING SOIL-BITUMEN SPECIMENS

Major Field: Civil Engineering

Biographical:

Personal data: Born in Pawhuska, Oklahoma, August 27, 1929, the son of Robert L. and Lois A. Manke.

Education: Attended grade school in Enid, Oklahoma; graduated from Spiro High School in 1947; received the Bachelor of Science degree from the Oklahoma Agricultural and Mechanical College, with a major in Civil Engineering, in May, 1956; completed requirements for Master of Science degree in May, 1957.

Professional experience: Entered the United States Army in 1950; attended Infantry Officer Candidate School at Ft. Benning, Georgia; had one year of overseas duty in Korea and was separated from service as a 1st Lieutenant in 1953; approximately two years of general construction work, and three months experience as a Materials Engineer with the Alaska Road Commission.

Professional organizations: Junior Member of the American Society of Civil Engineers.